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A COMPARISON OF THE LONGLEY-RICE SEMI-EMPIRICAL MODEL WITH THEORETICAL MODELS FOR COHERENT SCATTER

By

M. M. WEINER

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FOR THE COMMANDER

Richard L. Hocker

(Signature)
RICHARD L. HOCKER, Major, USAF
AF SINCGARS Program Manager
SEEK TALK System Program Office

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Longley-Rice semi-empirical propagation model is compared with theoretical models for coherent scatter of microwaves from moderately rough surfaces.

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The effect of terrain and sea roughness on coherent scatter of microwaves for a line-of-sight, multipath mode of propagation in the specular direction is given by the Longley-Rice prediction model as [1]

$$\langle \rho \rangle = \exp(-g^{1/2}/2) \quad (1)$$

where

$\langle \rho \rangle$ = expectation of the surface roughness field amplitude reflection coefficient

$g^{1/2}$ = surface roughness Rayleigh parameter

= $(2\pi/\lambda)\ (2 \sin \psi_i)\, \sigma_H$

λ = wavelength of incident radiation

ψ_i = grazing angle of incidence on mean surface level (MSL)

σ_H = standard deviation of the surface height random variable H with respect to the MSL.

This model differs from theoretical models which assume particular probability density functions for the height random variable. In particular, this model differs from theoretical models which assume that the height random variable is exponentially distributed[2], normally distributed[3,4], or pseudo-exponentially distributed[5]. The amplitude reflection coefficient $\langle \rho \rangle$ for these theoretical models are given by[2]

$$\langle \rho \rangle = \begin{cases} \exp(-g/2) & \text{normally distributed} \quad (2a) \\ \left(1 + \frac{2}{3} g\right)^{-3/4} & \text{pseudo-exponentially distributed} \quad (2b) \\ \left(1 + \frac{g}{2}\right)^{-1} & \text{exponentially distributed} \quad (2c) \end{cases}$$

Eq. (1) is a semi-empirical formula which has no theoretical basis but which was employed by Longley-Rice to fit empirical data[6,7]. The semi-empirical model of Longley-Rice and the theoretical models of Eq. (2) are compared with empirical data in Figs. 1-3 for microwave scatter from the ocean, microwave scatter from terrain and sea surfaces, and acoustical scatter from an artificial surface submerged in a water tank, respectively. It will be noted that the exponentially distributed model and the semi-empirical model give good agreement with data for both moderately rough and smooth surfaces. However, the semi-empirical model does not have zero slope at $g^{1/2} = 0$ as does the theoretical models and as does most of the empirical data.

In conclusion, the Longley-Rice semi-empirical model does not appear to offer any better fit to the empirical data than does the exponentially distributed model. The exponentially distributed model has the distinct advantages of having a theoretical basis and of offering an interesting physical interpretation of the stochastic process associated with the surface profile.[2]

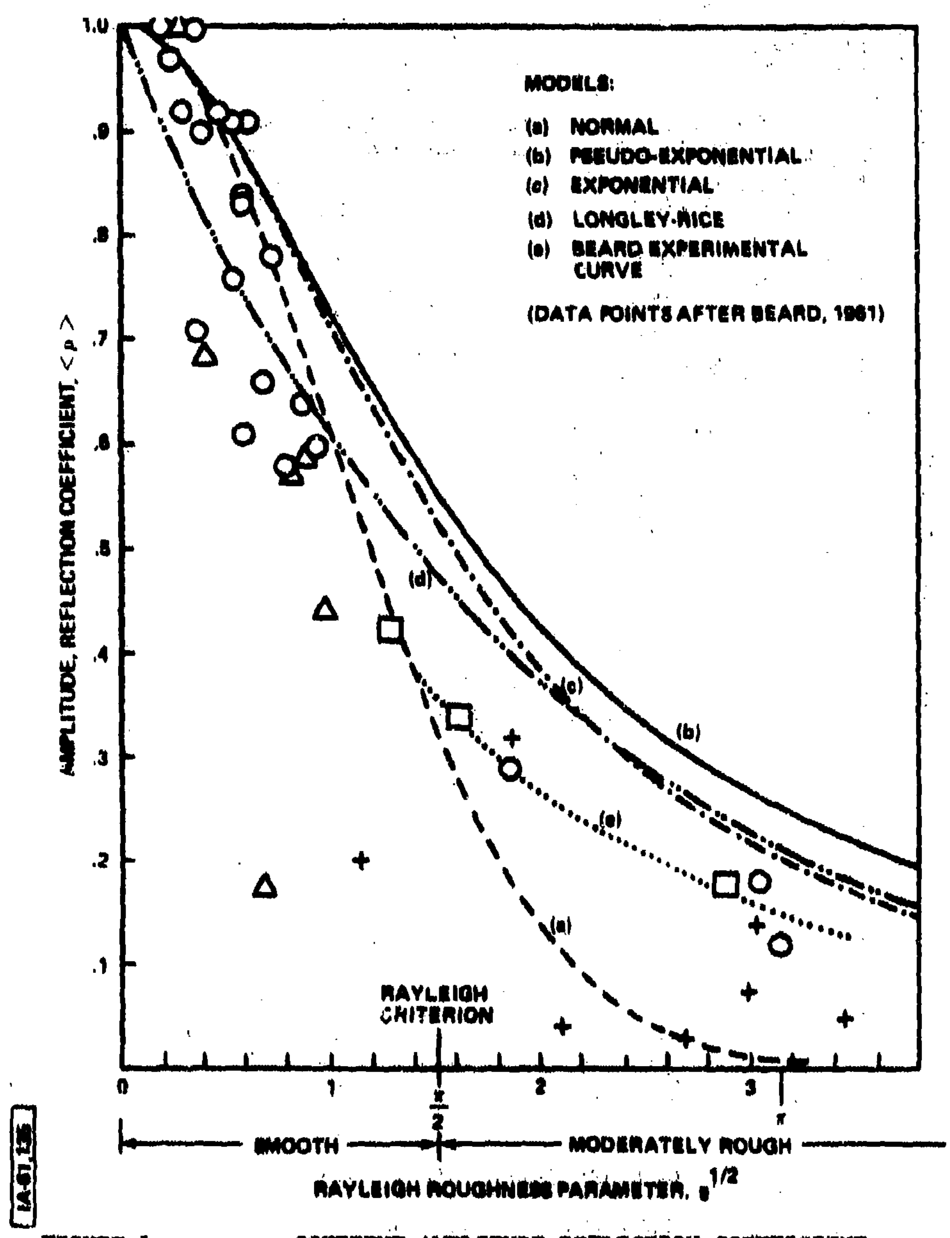

FIGURE 1. COHERENT AMPLITUDE REFLECTION COEFFICIENT. COMPARISON OF MODELS WITH EXPERIMENTAL DATA FOR MICROWAVE SCATTER FROM THE OCEAN.

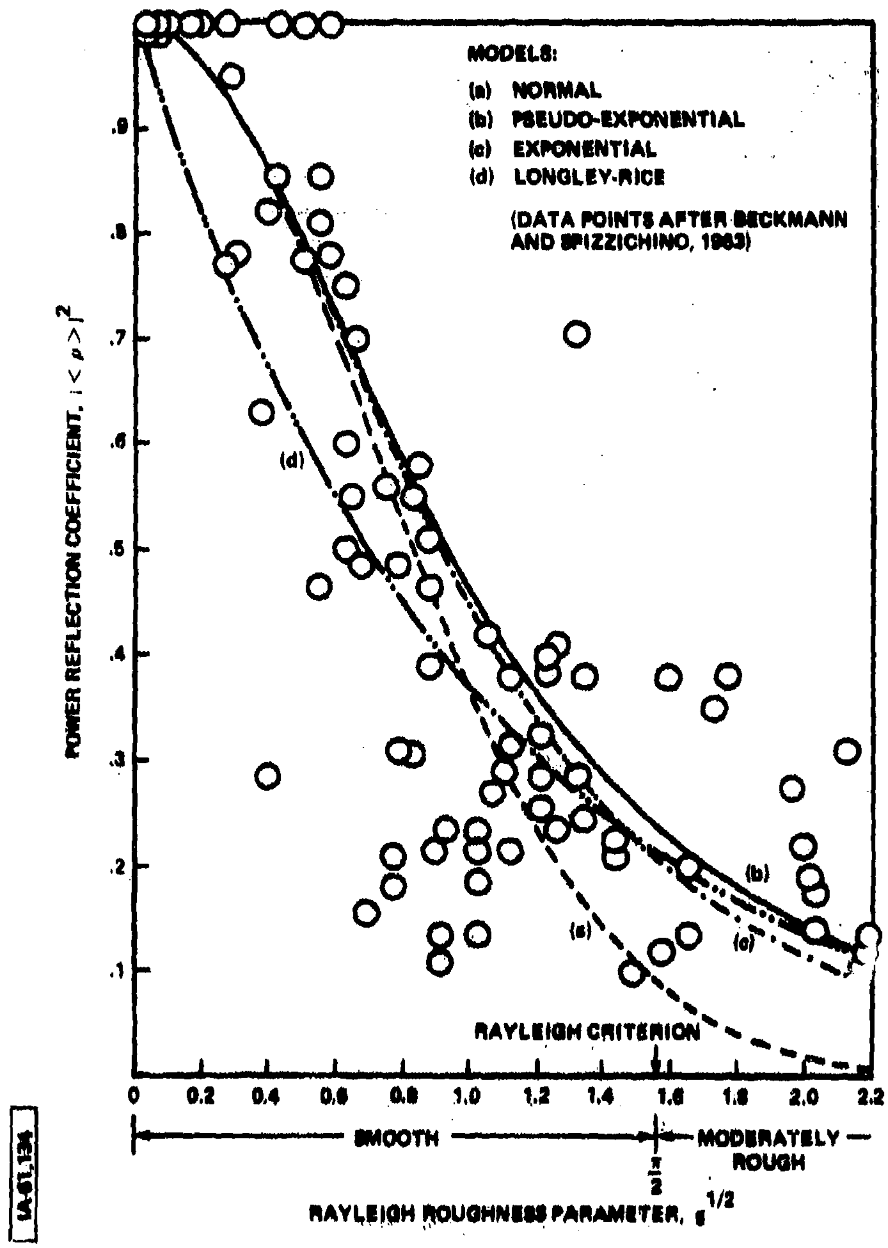

FIGURE 2. COHERENT POWER REFLECTION COEFFICIENT. COMPARISON OF MODELS WITH DATA FOR MICROWAVE SCATTER FROM TERRAIN AND SEA SURFACES.

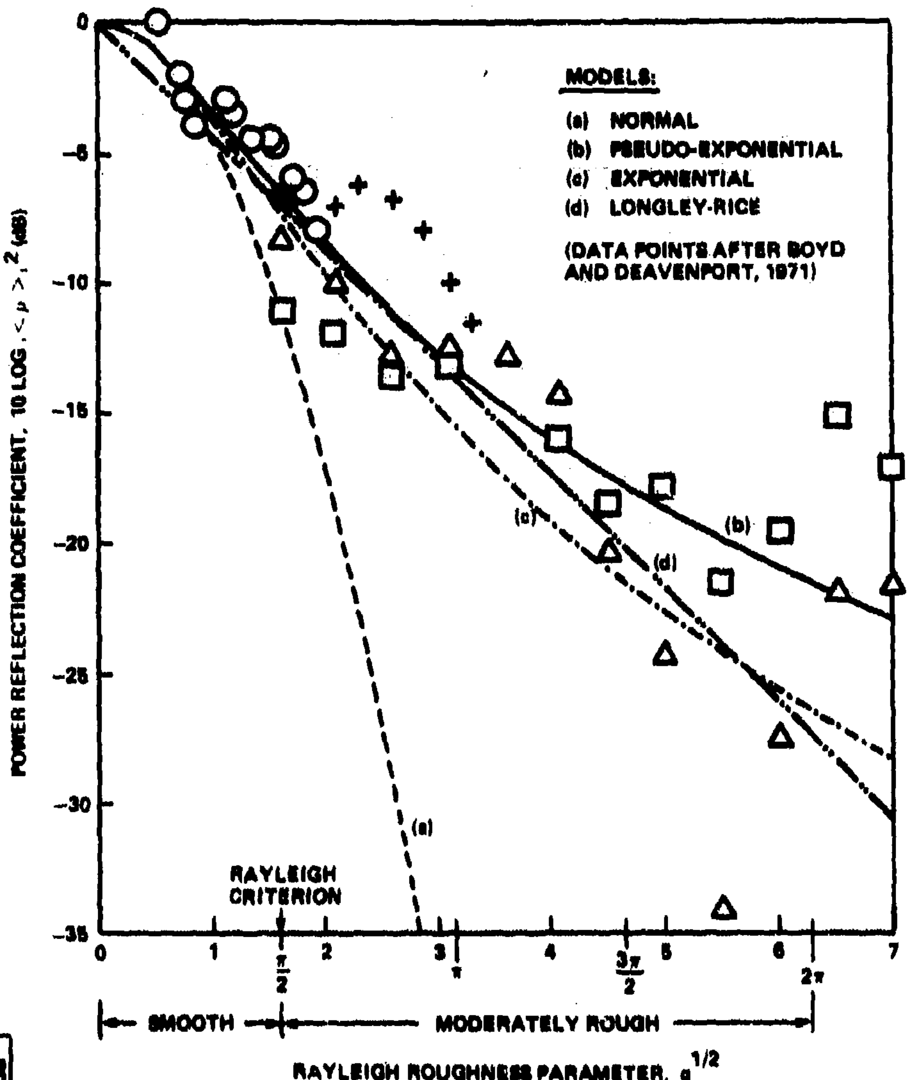

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FIGURE 3. COHERENT POWER REFLECTION COEFFICIENT. COMPARISON OF MODELS WITH EXPERIMENTAL DATA FOR SCATTER OF ACOUSTICAL WAVES FROM A SURFACE MODEL SUBMERGED IN A WATER TANK.

REFERENCES

1. A. G. Longley, and P. L. Rice, "Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain, A Computer Method - 1968", U.S. National Bureau of Standards, ESSA Tech. Report ERL 79-ITS 67, 1968, p. 3-3, Eq. (3.5), NTIS, AD 676 874.

2. M. M. Weiner and G. A. Robertshaw, "Coherent Scatter of Microwaves from Moderately Rough Surfaces," ESD-TR-81-147, The MITRE Corporation, Bedford, Mass., August 27, 1981, NTIS, AD A106 133.

3. P. Beckmann and A. Spizzichino, "The Scattering of Electromagnetic Waves from Rough Surfaces" (Pergamon Press, Oxford, 1963) pp. 246-247.

4. C. I. Beard, "Coherent and Incoherent Scattering of Microwaves from the Ocean, IRE Transactions on Antennas and Propagation, Vol. AP-9, pp. 470-483 (September 1961).

5. M. L. Boyd and R. L. Deavenport, "Forward and Specular Scattering from a rough surface; Theory and Experiment", J. Acoust. Soc. of America, Vol. 53, pp. 791-801 (March, 1971).

6. Telephone conversation with P. L. Rice on February 19, 1981.

7. M. M. Weiner, "Terrain and Sea Surface Truth: Profile Distributions", ESD-TR-81-387 (The MITRE Corporation, Bedford, MA, December 1981), NTIS, AD A110 219.